THE CONTRIBUTION OF OPERATIONAL RESEARCH AT NATIONAL DEFENCE

by

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ABSTRACT

This paper was prepared by CORAE as a contribution to a session of the Canadian Operational Research Society dealing with the contribution of operational research to planning. It gives an outline of the development of operational research in DND and shows how the work done relates to the requirements of military planners within the Department.

THE CONTRIBUTION OF OPERATIONAL RESEARCH AT NATIONAL DEFENCE

Operational Research had its origin as research on military operations shortly before the outbreak of World War II, and its great initial development in analysis of actual operations of war, during which time its value was very clearly demonstrated, at both the tactical and strategic levels, as well as for the design and employment of weapon systems.

Since the end of World War II there has been little opportunity for study of actual operations of war in the Canadian Armed Forces, and the character of the O.R. done in the Department of National Defence has changed in its emphasis through the last thirty years.

During the 1950's, a time of modernization and expansion, there was much need for O.R. in planning for new equipment, and in development of the best tactics and procedures to exploit the new equipment. In the absence of real operations of war, the best possible use had to be made of field exercises and war games.

The 1960's brought retrenchment in defence with decreasing budgets forcing reductions in manpower, and inability to replace aging equipment. They also brought unification of the Armed Forces, with consequent major changes in organization and procedures. During this period, O.R. moved into the area of logistics and of manpower analysis.

During the 1970's, there have been searchings into the problems of international stability, and into the rationale for Canadian defence forces. These produced a need for a new type of defence research, involving strategic and social studies, which have been undertaken by DND's Operational Research and Analysis Establishment, although it is questionable whether they should be described as Operational Research. Another major change was the provision of substantial sums of new money for badly needed new capital equipment, to be acquired through a systematic planning process. In support of these programs, ORAE found itself engaged in research probably better described as systems analysis than as O.R.

For the remainder of my time, I shall give examples of these various types of work. They are all defence research. If you accept the definition that O.R. is what operational researchers do, then they are also O.R. If you prefer another definition, I will leave it to you to decide how many of them are operational research.

The three types of weapon systems that have occupied the most attention by our analysts are anti-air, anti-submarine, and anti-tank. Good reasons for this are that our most likely enemies are very well provided with aircraft, submarines, and tanks. From an analytical point of view, these three problems have both similarities and differences. All three can be divided up into phases of detection and attack. But the detectability of an aircraft by radar is fairly easy to calculate, predict, and model - that of a submarine by sonar much less so; and that of a tank by eye is dominated by the details of terrain, background, and atmospheric conditions. Given detection, the attack on an aircraft, submarine, or tank is comparatively straightforward to analyse unless the target is fighting back. However, it is very likely to be fighting back, and in the case of a tank its friends are also likely to fight back. Rather than rely on calculation, one would prefer realistic exercises. Obviously in an exercise, the target cannot be killed, but, short of this final step there is a high degree of realism in both air defence and anti-submarine exercises, and a good opportunity to collect and record data which can be used to predict whether a kill would have been obtained. The number of units involved in a particular engagement is normally very small, perhaps as low as one aircraft vs. one aircraft, or one ship or one aircraft versus one submarine. It is comparatively easy to put the necessary recording instrumentation into an aircraft or a ship, and to reconstruct the movements after the engagement.

These considerations appear very different with anti-tank exercises, where many units of various types are simultaneously engaged, where the circumstances of intervisibility are usually very complicated, and where it is not usually possible to record movements or weapon engagement data.

Because of these many practical difficulties in deriving analytical results from army field exercises, a great deal of effort has been devoted to the design, play, and analysis of war games. The Canadian land/air war game goes into extreme detail, and as a result, takes a long time to prepare and is very slow to play. It requires an elaborate book of rules based on many analytic models of factors such as detection time lapses, and kill probability of various weapons against various targets. It is organized into three components, carefully separated in separate rooms; the two opposing sides, blue and orange, and control. The passage of information between rooms is carefully controlled. Attempts to speed up the game by on-line computer assistance have not been successful, but the computer is very useful for record keeping, reconstruction, and calculation of many details needed for decision by control.

Naturally, military planners need all the analytical evidence that can be provided, to answer questions for the future such as:

- Will new precision-guided weapons prove the answer to the tank?
- Will modern surface-to-air missiles drive aircraft away from the battlefields of the future?
- Can surface ships survive against modern aircraft armed with anti-shipping missiles?
- Can there be an effective defence against modern submarines armed with anti-shipping missiles?

Of all the problems related to weapons and tactics, anti-submarine warfare is probably the most fruitful subject for peacetime O.R. Sonar offers endless material for operational analyses, whether hull-mounted, towed, fixed, or in sonobuoys. Sonobuoys themselves come in many forms, including active and passive, directional and anti-directional, free-floating and moored, continuous and command activated. The introduction of the Argus MPA allowed many years of productive O.R. Plans for the ASW hydrofoil involved O.R., but in the end the project was abandoned because of high cost. Planning for the Aurora LRPA began about fifteen years before initial delivery, and O.R. studies had a large part to play in refining the requirements and making the selection, especially as regards the type of avionic equipment to be acquired.

There is also a lot of systems analysis being performed in the process of selecting the New Fighter Aircraft and the Canadian Patrol Frigate. In all three cases, the total amount of money available for acquisition has been specified, so that the problems are those of optimizing the return from a known investment. However they are by no means simple, since several military roles are involved and it is necessary to take account of many economic aspects of the programs such as industrial benefits.

In the case of the patrol frigate, the present studies are concentrating on six ships of orthodox design. But it is quite possible that the follow-on class could be of a radically new type.

Many of the operational aspects of continental air defence have offered good material for operational research, both in planning systems and in developing procedures. In particular, the performance of radar, the processing of information, the passage of warning, and the direction of interceptor aircraft have been very extensively studied. In some cases, the performance of the human operator has been overtaken by computers, and the computers can be used to record data previously not kept.

It is interesting to compare the information processing in the air defence and the anti-submarine systems. Things move much faster in the former, and detection, almost always by radar, is fairly reliable and predictable unless electronic warfare is being used. Identification can be a problem, especially if there is a fair density of civil air traffic. But detection of submarines may occur by any of several different means, none of which are very reliable or predictable. The overall picture changes slowly, and the data are full of uncertainty.

Three other areas of air operations which have been subject to continuing O.R. are planned flying planned maintenance, mathematical models of air-sea lift, and search and rescue. The objective of planned flying planned maintenance is to establish the relationship among the schedule of flying from an air base, the size of the air crews, and the size and scheduling of the maintenance crews. Once this is known, a change in one can be matched by the appropriate changes in the other two. In the case of air/sea lift, the problem is to schedule cargo aircraft and possibly also cargo ships in such a way as to deliver a specified mixed load in a specified order, using specified airfields, and taking account of expected weather and unserviceability. A computer model allows this to be done quickly for any set of inputs. These last two problems are similar in many ways to those faced by civil airlines, except that they are oriented towards situations occurring once only rather than those applying continuously over a long period. Search and rescue, which also can involve ships as well as aircraft, offers applications of the mathematical theory of search, mixed with the collection of various operational data related to the circumstances of a particular search, likely to have information available of degrees of reliability and to be subject to different degrees of urgency.

Unification of the CAF offered opportunities to rationalize the supply system, formerly acquiring and feeding three sets of materiel through three separate networks of depots, and quite apart from unification, logistics offers many problems very suitable for analysis, including policies for maintenance, repair and replacement, for inventory stocks, for handling of lifed items, and for the provisioning of an initial set of spare parts for a newly acquired ship, aircraft, tank, or other major system with a long expected life.

This type of logistical analysis has many parallels in industry, but important differences are present too. While cost is a major consideration, there is no profit to be made, and it is difficult to impute a realistic cost to a stockout or failure. The variety of items in the system is simply enormous, and the rates of turnover cover a very wide range. There is a role for marginal analysis, so that the investment in spare parts is well distributed with regard to risks and costs.

Rationalization of the supply system had a counterpart in manpower policy when the CAF were unified. Many specialized trades could be merged among land, sea, and air, although this posed certain problems in training, rank structure, and pay grading. The number of personnel involved, the large number of highly standardized categories, and the importance of planning careers over a period of many years all pointed to analysis by mathematical models, although the use of computers to deal with personnel problems is anathema in some quarters. One significant advantage of a good model is to indicate the long-term consequences of an immediate change in policy, in an area where the system cannot await or tolerate the method of trial and error. Development of the theory of goal programming has been followed by very useful practical results in our analysis of manpower problems in the CAF.

Another application of analytic methodology to a practical problem in personnel administration has been made for the transfer of servicemen between posts in a particular trade group. Many factors need to be taken into account, with a certain limited degree of flexibility acceptable in most of them. For example, a radar crew established at a strength of eight could probably survive for a limited period with only six, and could usefully employ ten. A posting usually set for three years could be reduced to two or extended to four. Constraints may need to be applied to particular posts or particular individuals, perhaps on grounds of language or medical requirements, whether of the serviceman or his dependents. In general the requirements of the organization can be put into the computer program, and its solution is then subject to human veto on grounds of requirements of the individual.

Finally, a few words may be in order regarding the excursion of ORAE into strategic studies and social and economic analysis. Whether they are O.R., systems analysis, policy analysis, or something else, they do represent an area of research needed by the DND, and not provided elsewhere in the established structure of the department.

One area of increasing interest is that of arms control. In principle a country or an alliance could obtain security by either of two methods: it could unilaterally design and build military forces sufficient to offset those of its principal adversary, or it could attempt to negotiate with the adversary a level of forces on both sides that would leave each in a relative position sufficiently strong to provide a tolerable degree of security. The second approach requires cooperation, and a certain common appreciation of many factors. A prerequisite is a comprehensive analysis of the situation at present and what could develop in the future. NATO does undertake such analyses, depending on its member countries for the studies, discussion, and criticism.

When the possibility is discussed that a new CF base may be opened, or more frequently in the current climate that an existing base may be closed, there are many factors to be considered in addition to the value of the base for military operations. Depending on the circumstances, a CF base may have considerable impact on the surrounding civilian community, both social and economic. Evidently this impact is strongest if the base is large and the surrounding community small. It is important to evaluate both effects before decisions are made.

When a decision is pending regarding some operational unit, such as the transfer of an army unit, the paying off of a ship, or the replacement of a particular type of aircraft, the department wants to know what the costs (or savings) will be. The direct costs are easy enough to identify, but associated with them are many related second and third-order costs, such as personnel, training, and support facilities. An ultimate objective is a model which would track all of these costs, but it has proved to be a surprisingly complicated matter.

These last types of studies, in the strategic, social and economic areas, may not strike one as well-suited for the graduates of courses in mathematical optimization or queueing theory. Many of our analysts took their formal training in physics, chemistry, or engineering, which may seem even farther removed from the study of strategy, sociology, or economics. However, when mixed with a few graduates in history or political science, they seem to be well able to attack these problems. The work may not be operational research, or even systems analysis, but it is relevant to the main problems that confront the Department of National Defence. The changes in our research programs over the years have been made in response to the needs of our employers, a very necessary policy for an in-house O.R. organization that wishes to survive.

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